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Germplasm Evaluation in Beef Cattle–Cycle IV: Birth and Weaning Traits[1,2,3]

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ABSTRACT: Gestation length, unassisted calving percentage, perinatal mortality, calf crop weaned (survival from birth to weaning), birth weight, and 200-d weaning weight of 2,597 calves born and 2,433 calves weaned are reported for F_1 crosses resulting from matings of Angus, Hereford, Charolais, Gelbvieh, Pinzgauer, Shorthorn, Galloway, Longhorn, Nellore, Piedmontese, and Salers sires to Angus and Hereford dams (≥ 3 yr of age) in Cycle IV of the Germplasm Evaluation (GPE) Program at the U.S. Meat Animal Research Center. Hereford and Angus sires included 1) reference sires born from 1963 to 1971 used in previous cycles of the GPE Program, 2) sires born from 1982 to 1985 (1980s), and 3) sires born from 1983 to 1985 used in natural service clean-up matings. Effects of sire breed of calf were significant for gestation length, unassisted calving percentage, birth weight, and 200-d weaning weight. Gestation length was significantly longer for Nellore than for Charolais, Galloway, Longhorn, Piedmontese, and Salers, which were in turn longer than for Hereford-Angus and Shorthorn. Rankings for birth weight tended to be inversely related to those for calving ease, except for Shorthorn and Salers sires, which required low assistance relative to their heavy birth weights. Rankings for 200-d weight among AI-sired progeny were as follows: Charolais (231.3), Nellore (229.7), Salers (225.5), Shorthorn (223.8), 1980s Hereford-Angus (223.1), Piedmontese (220.0), Galloway (209.5), reference Hereford-Angus (210.1), and Longhorn (199.0); differences ≥ 6.5 kg were significant.

Key Words: Beef Cattle, Breeds, Germplasm, Gestation Length, Survival, Growth

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Introduction

Breed differences in performance characteristics are important genetic resources for improving the efficiency of beef production. Diverse breeds can be crossed to exploit heterosis and complementarity and to match genetic potential with markets, feed resources, and climates. This article reports results from the fourth cycle of the Germplasm Evaluation (**GPE**) Program at the Roman L. Hruska U.S. Meat Animal Research Center (**MARC**). The program's primary objective has been to characterize cattle breeds representing diverse biological types for traits of economic importance to beef production. In this report, results are presented for gestation length, calving difficulty, perinatal mortality, calf crop weaned, birth weight, and 200-d weight of progeny by Hereford, Angus, Shorthorn, Galloway, Longhorn, Nellore, Piedmontese, Salers, Charolais, Gelbvieh, and Pinzgauer sires with Hereford and Angus dams. A review that compares topcrosses by 20 sire breeds was presented by Cundiff et al. (1986), who pooled results from Cycle I (Smith et al., 1976; Notter et al., 1978a,b), Cycle II (Gregory et al., 1978; Setshwaelo et

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al., 1990), and Cycle III (Gregory et al., 1979) of the GPE Program.

Materials and Methods

Data were obtained on 2,597 calves born and 2,433 calves weaned at the U.S. MARC from 1986 to 1990. The experimental design is reflected in Table 1, which shows the number of calves born and weaned per breed group of sire and breed group of dam subclass.

The dams were registered Angus and Hereford cows. The Angus population (MARC Angus) had a long history of selection for growth rate. The Hereford cows represented five experimental lines of breeding. Most of the Hereford cows were produced in a long-term selection project comprised of four closed lines: 1) an unselected control that represented a broad sample of the Hereford breed assembled in about 1960 (**CTL**); 2) a line selected for 200-d weaning weight from 1960 to 1979 (**WWL**); 3) a line selected for 400-d yearling weight (**YWT**) from 1960 to 1979; and 4) a line selected for an index of yearling weight and muscling score (**IXL**) from 1960 to 1979 (Koch et al., 1995). Selection was relaxed in all lines during terminal phases of the selection project from 1980 to 1985. The fifth set of Hereford cows (MARC Herefords), founded by crossing the WWL, YWL, and IXL populations, were under continuous selection for direct and maternal weaning weight and yearling weight, and included some subsequent outcross matings to bulls selected from the Prospector Line at Colorado State University and Line 1 at the USDA-ARS Station at Miles City, MT. Comparisons among the Hereford lines from the present analysis were consistent with results reported by Koch et al. (1995) and will not be presented in this report.

Table 2 shows the number of bulls used in each sire breed by AI and natural service clean-up (**CU**) matings by year of calving. The plan was to produce about 200 calves by about 25 to 30 bulls per sire breed used by AI. Shorthorn, Galloway, Longhorn, Nellore, Piedmontese, and Salers sires were used for the first time in Cycle IV in AI matings. Hereford-Angus reciprocal crosses have been produced in each cycle of the program using a common set of original reference sires by AI. In Cycle IV, more recently born (1980s) samples of Hereford and Angus were added to evaluate genetic trends within these breeds and to provide for more contemporary comparison of sire breeds. In addition, a sample of Charolais sires born from 1983 to 1985 were used in AI and CU matings. Following an AI period of approximately 45 d, two to five bulls each of the Angus, Hereford, Charolais, Gelbvieh, and Pinzgauer breeds were used in CU matings.

In Hereford and Angus sire breeds, an original set of reference sires that had been used in Cycles I, II,

Table 1. Number of calves born (Bn) and weaned (Wn) by breed group of sire and breed group of dam subclass

	Breed of dam subclasses[a]													
			Hereford											
	Angus		CTL		WWL		YWL		IXL		MARC		Total calves	
Breed group of calf	Bn	Wn	Bn	Wn	Bn	Wn	Bn	Wn	Bn	Wn	Bn	Wn	Bn	Wn
Reference Angus	93	89	39	37	20	20	12	12	12	12	3	3	179	173
Reference Hereford	106	101	32	30	16	16	13	13	14	12	4	4	185	176
1980s Angus AI	52	49	19	17	7	7	7	6	11	10	3	2	99	91
1980s Angus CU[b]	54	52	25	24	11	9	14	13	16	14	2	2	122	114
1980s Hereford AI	55	54	16	15	11	11	6	5	9	9	4	4	101	98
1980s Hereford CU[b]	55	49	21	21	13	11	17	15	12	12	2	2	120	110
Charolais AI	50	44	16	14	12	12	7	7	3	3	2	2	90	82
Charolais CU[b]	45	38	28	26	13	12	13	12	11	11	3	3	113	102
Gelbvieh CU[b]	97	89	50	48	24	21	23	22	28	27	4	4	226	211
Pinzgauer CU[b]	88	84	50	49	31	28	21	19	32	29	2	2	224	211
Shorthorn	98	93	39	35	12	11	13	13	16	15	3	3	181	170
Galloway	95	89	33	31	16	16	14	13	13	13	1	1	172	163
Longhorn	115	105	31	30	19	18	16	16	16	14	3	3	200	186
Nellore	104	99	34	29	14	12	18	17	20	20	6	6	196	183
Piedmontese	110	103	37	32	14	13	21	21	13	12	5	5	200	186
Salers	109	102	32	30	13	11	15	15	13	13	7	6	189	177
Total	1,326	1,240	502	468	246	228	230	219	239	226	54	52	2,597	2,433

[a]CTL = control line, WWL = weaning weight line, YWL = yearling weight line, IXL = index for yearling weight and muscling score line, and MARC = Hereford population selected primarily for yearling weight.
[b]Calves sired by natural service matings after a breeding period of 45 d by AI.

Table 2. Number of sires used each year

Sire breed	1986	1987	1988	1989	1990	Total[a]
	Number of sires					
Reference Angus	13	13 (12)[b]	10 (10)	16 (10)	10 (9)	21
Reference Hereford	10	10 (10)	7 (7)	9 (9)	9 (9)	10
1980s Angus AI	12	8 (7)	9 (3)	11 (4)	10 (7)	28
1980s Angus CU[c]	3	2 (0)	2 (0)	2 (0)	2 (0)	11
1980s Hereford AI	15	12 (6)	10 (4)	9 (6)	9 (9)	30
1980s Hereford CU[c]	4	2 (0)	2 (0)	2 (0)	2 (0)	12
Charolais AI	15	7 (4)	7 (7)	12 (2)	13 (12)	29
Charolais CU[c]	2	2 (0)	2 (0)	2 (0)	2 (0)	10
Gelbvieh CU[c]	5	4 (1)	4 (0)	3 (0)	3 (0)	18
Pinzgauer CU[c]	5	4 (3)	4 (0)	3 (0)	3 (0)	16
Shorthorn	15	13 (7)	11 (7)	10 (10)	17 (17)	25
Galloway	11	13 (6)	12 (7)	12 (7)	12 (10)	30
Longhorn	15	14 (7)	18 (5)	11 (8)	9 (9)	28
Nellore	17	17 (17)	11 (6)	12 (12)	7 (7)	22
Piedmontese	7	10 (7)	11 (7)	5 (2)	8 (3)	22
Salers	16	14 (7)	15 (13)	11 (9)	7 (7)	27

[a]Total number of different sires used.
[b]Number of sires that were repeated from a previous year are shown in parentheses.
[c]Calves sired by natural service matings after a breeding period of 45 d by AI.

and III of the GPE Program were compared with the 1980s sample of sires to evaluate genetic trends in Hereford-Angus reciprocal crosses. Reference Herefords included four polled sires and six horned sires born from 1963 to 1969. Reference Angus sires included 14 sires born from 1968 to 1970. The reference Angus that were originally sampled to initiate Cycle I of the GPE Program in the 1969 to 1971 breeding seasons were selected as yearlings on the basis of individual performance records for entry into progeny testing programs of AI organizations. In addition, semen from seven sons (progeny of 6 of the 14 reference Angus sires produced at MARC in 1980 out of MARC Angus cows) was used to produce 29 of 183 of the reference-sired progeny. Semen from these sons of reference sires was needed to supplement the short supply of semen on reference Angus sires to produce calves in the 1989 and 1990 calf crops.

The more recently born 1980s Hereford sires included 14 horned sires born from 1982 to 1985 and 18 polled sires born from 1983 to 1985. The 1980s Angus sires included 28 Angus sires born from 1983 to 1985. All 1980s bulls were chosen at young ages before data were available on their progeny to affect accuracy of selection. Five of the Hereford sires and 19 of the Angus sires used AI were sampled from AI organizations. The remaining AI sires were sampled from two Angus breeders, six polled Hereford breeders, and 11 horned Hereford breeders. Angus sires used in CU matings were from the MARC population except for two Angus sires by prominent industry sires purchased from the University of Nebraska. Hereford sires used in CU matings were produced in the MARC Hereford population, usually from outcross matings to Line 1 (MacNeil, 1992) or Prospector Line (Brinks and Knapp, 1975) sires, or in the Germplasm Utilization (**GPU**) Program (Gregory et al., 1991) Hereford population, except for two bulls by prominent industry sires purchased from the University of Nebraska.

With the assistance of cooperating representatives of each breed association, Shorthorn, Galloway, Longhorn, Piedmontese, and Salers sires were sampled from a large number of herds (usually only one sire per herd) in each breed. The Nellore sires included 20 sires imported into the United States from Brazil by a private breeder (W. Wilson, Overton, TX) in 1982 and two sires sampled from more recent semen importations by American Breeders Service, DeForest, WI.

Charolais-sired progeny were by 29 sires used in AI matings and 10 sires used in CU matings. The AI sires were sampled from 27 private breeders, and the 10 sires used in CU were produced at MARC in the GPU Program (Gregory et al., 1991). The Gelbvieh and Pinzgauer sires used only in CU matings were produced at the MARC in the GPU Program. Each of these populations was founded on a broad sample of 20 or more foundation sires (Gregory et al., 1991).

Dams were maintained on improved pasture (April to November). In April to June and later in September to November, they were maintained on predominantly cool season smooth bromegrass (*Bromus inermis*). In June to September, they were maintained on warm season mixtures of predominantly big bluestem (*Andropogon gerardii*), switch grass (*Panicum virgatum*), indian grass (*Sorghastrum nutans*), with some little bluestem (*Schizachyrium scoparium*), sideoats grama (*Bouteloua curtipendula*), and sand lovegrass (*Eragrostis trichoides*). During winter months (December to

March), the dams were fed grass and alfalfa hay (or corn silage and alfalfa hay) on pasture. Calves were born in the spring, beginning in late March and ending in late May. The average birth date was April 25. Calves were weighed, tattooed, and tagged for identification. Male calves were castrated within 24 h after birth. Calves were creep-fed whole oats from mid-July until weaning in early October. Calves averaged about 170 d of age at weaning.

The cows were observed closely for calving difficulty. Cows that calved with no assistance and those given minor hand assistance, which delivered without the aid of a mechanical calf puller, were classified as unassisted. Those that required assistance with a mechanical puller or surgical removal of the calf were classified as difficult. Abnormal presentations were also classified as difficult parturitions. Perinatal mortality included all stillbirths and calves that died within 72 h after parturition. Calf crop weaned relative to all cows calving reflects variation in survival from birth to weaning (1 = live calf weaned, 0 = stillbirth or calf died between birth and weaning). Calf crop weaned was not computed relative to all cows exposed because, with semen obtained from a vast number of herds and AI centers, inherent differences in fertility of sires and sire breeds were confounded with a variety of environmental sources of variation that affect semen quality. Consistent with previous reports, weights taken at weaning were adjusted to 200 d by multiplying average daily gain from birth to weaning by 200 and adding birth weight.

Data were analyzed using least squares mixed model procedures (Harvey, 1985). The model for gestation length and traits recorded on all calves born (i.e., unassisted calving, perinatal mortality, calf crop weaned, and birth weight) included the following fixed effects: for sire breed group (**B**: "reference" Hereford used by AI, "1980s" Hereford used by AI, Hereford used in natural service clean-up matings, "reference" Angus used by AI, "1980s" Angus used by AI, Angus used in natural service CU matings, Charolais used by AI, Charolais used in natural service CU matings, Gelbvieh, Pinzgauer, Shorthorn, Galloway, Longhorn, Nellore, Piedmontese, and Salers), for dam breed (**D**: Hereford, Angus), for line within D (**L/D**: control, weaning weight line, yearling weight line, index line, MARC population in Herefords), for sex of calf (**S**: male and female), for age of dam (**A**: 3, 4, 5–9, 10, 11, ≥12 yr of age), for birth year (**Y**: 86, 87, 88, 89, and 90), for all two-factor interactions among these fixed effects, and for a random effect for sires nested within breed of sire. The model was reduced for each trait to include only B × D and significant two-factor interactions. The sire within breed of sire mean square was used as the error term to test effects of B and B × D, and for 200-d weight, B × S. The residual error mean square was used to test other fixed effects in the model. The model for 200-d weight, involving all calves weaned, was the same as for traits on all calves born except that it included date of birth as a covariate. The least significant difference (**LSD.05**; $P < .05$) was computed for all possible pairwise contrasts using the sire within breed of sire mean square as the error term in the linear contrast procedure of Harvey (1985). Because a table of 66 contrasts for each trait was difficult to comprehend, only the mean LSD.05 for each trait is presented as a guide for assessing significance of breed differences. Breed group differences greater than the LSD.05 were considered statistically significant ($P <$ .05). Estimates of heritability, genetic variance (σ_g^2), and phenotypic variance (σ_p^2) were computed using least squares mixed model procedures (Harvey, 1985).

Hereford and Angus sires were mated to produce straightbred and reciprocal-cross progeny to estimate genetic trends for direct and maternal breed components of performance. However, results from the Hereford-Angus diallel matings will be presented in a separate report. For Hereford- and Angus-sired progeny, results presented here will be only for F_1 crosses that resulted from AI matings by reference and 1980s Hereford and Angus sires and by CU Hereford and CU Angus sires. Thus, in this report all sire breed contrasts estimate half of the additive genetic differences between direct effects of breeds plus any difference between specific heterosis effects of specific breed crosses with Hereford and Angus. Differences in heterosis of specific *Bos taurus* × *Bos taurus* breed crosses from the general or average effect of heterosis over all *Bos taurus* × *Bos taurus* breed crosses are expected to be relatively small (e.g., Long, 1980); however, Nellore crosses are expected to benefit from extra heterosis of *Bos indicus* × *Bos taurus* heterosis (e.g, Cartwright, et al., 1964; Koger et al., 1975). Thus, estimates from the present study would underestimate (or overestimate) pure breed differences for additive direct effects between Nellore and the *Bos taurus* breeds, but are appropriate for drawing inferences from comparisons of crossbreeding systems that involve *Bos taurus* × *Bos taurus* crosses vs *Bos indicus* × *Bos taurus* crosses, especially when Herefords or Angus are included in the cross, as often is the case in North American beef production.

Results and Discussion

Mean squares for all traits are presented in Table 3. Effects of year of birth, sex of calf, and age of dam were significant for gestation length, unassisted calving percentage, birth weight, and 200-d weight. Results for effects of sex of calf and age of dam for these traits were consistent with previous estimates (e.g., Smith et al., 1976; Gregory et al., 1978; Gregory et al., 1979) and will not be presented or discussed in this report. Within Hereford dams, progeny of control line females were significantly lighter than those of all other lines of dam, and birth weight did not differ significantly among lines selected for weaning weight, yearling weight, or an index of yearling weight and muscling score (data not shown), consistent with previous results (Koch et al., 1995). It was important to include their effects in the analytical model to estimate breed effects unbiased by their influence. Least squares means and standard errors for sire breed groups are presented in Table 4 for all traits. Our discussion focuses primarily on effects of sire breed first (B) and on statistically significant interactions of sire breed with breed group of dam or with sex of calf.

Gestation Length. Gestation length, available only on progeny that resulted from AI matings, was affected significantly by direct genetic effects of sire breed, sire within sire breed, dam breed, and line within Hereford dams. Interactions of sire breed × dam breed and other two-way interactions among fixed effects were not significant for gestation length. The overall mean for gestation length was 285.7 d. Gestation length was significantly shorter for progeny of Hereford, Angus, and Shorthorn sire breeds than for progeny of Charolais, Galloway, Longhorn, Piedmontese, and Salers sire breeds. Salers-sired progeny had longer gestation lengths than Hereford- or Angus-sired progeny ($P < .05$), but these did not differ significantly from the gestation lengths of progeny of Shorthorn, Galloway, or Charolais. Progeny of Nellore sires had significantly longer gestation length than those of any other sire breed. Previous reports of direct genetic breed effects on gestation length have also shown significantly longer gestation length for progeny by *Bos indicus* sire breeds (e.g., Brahman and Sahiwal, Gregory et al., 1979) and for progeny by Continental European *Bos taurus* sire breeds than for British sire breeds (e.g., Charolais, Limousin, and Simmental [Smith et al., 1976]; Braunvieh, Gelbvieh, and Chianina [Gregory et al., 1978]; Tarentaise and Pinzgauer [Gregory et al., 1979]).

Consistent with previous reports (Smith et al., 1976; Gregory et al., 1978, 1979), gestation length was significantly longer for progeny of Hereford (286.8) dams than for progeny of Angus (284.5) dams. Gestation length has not been reported previously for Hereford lines selected for weaning weight (WWL = 286.7 ± .48), yearling weight (YWL = 286.9 ± .50), and index of yearling weight and muscling score (IXL = 288.4 ± .50) relative to the unselected control line (CTL = 286.1 ± .39) because this is the first report of data from AI matings. The total numbers of progeny on which gestation length was recorded were 154 for the WWL, 142 for the YWL, 140 for the IXL, 328 for the CTL line, and 41 for the outcrossed MARC line. Gestation length was significantly longer for progeny of IXL dams than for progeny of dams of all

Table 3. Mean squares for birth and weaning traits

Source	df[a]	Gestation length, d	Unassisted calving, %	Perinatal mortality, %	Calf crop weaned, %	Birth weight, kg	200-d weight, kg
Sire breed (B)	15	1,463.1**	1,028**	309	504	1,108**	14,317**
B × D	15	10.5	410	268	553	40*	978
B × S		—	—	—	—	59*	—
Sire/B[b]	322	32.8**	380*	420*	625	33**	702**
Dam breed (D)	1	1,267.6**	620	156	112	496**	88,813**
Sex (S)	1	1,242.5**	4,240**	1,562*	1,380	5,158**	112,301**
Age dam (A)	5	63.1**	904*	514	423	204**	8,923**
Year birth (Y)	4	205.9**	463	907	572	140**	8,921**
Line/D	4	108.3**	460	1,294**	618	735**	16,660**
D × Y		—	—	—	—	51**	4,940**
S × Y		—	—	—	—	—	2,089**
A × Y		—	—	—	—	62**	1,409**
b1 (birthday)	—	—	—	—	—	—	6,662**
Residual	2,217	19.7	321	359	580	20	529

[a]Degrees of freedom (df) are for unassisted calving percentage, perinatal mortality percentage, and survival from birth to weaning. Corresponding df for gestation length are 10 for B, 259 for sire/B, 1 for D, 1 for S, 5 for A, 4 for Y, 4 for line/D, 10 for B × D and 1,494 for residual. Corresponding df for birth weight are 15 for B, 322 for sire/B, 1 for D, 1 for S, 5 for A, 4 for Y, 4 for line/D, 15 for B × D, 15 for B × S, 4 for D × Y, 14 for A × Y, and 2,196 for residual. Corresponding df for 200-d weight are 15 for B, 320 for sire/B, 1 for D, 1 for S, 5 for A, 4 for Y, 4 for line/D, 15 for B × D, 4 for D × Y, 4 for D × Y, 4 for B × S, 14 for A × Y, 1 for regression on date of birth, and 2,044 for residual.

[b]Sire/Sire breed mean square was used as the error term to test effects of sire breed, sire breed × dam breed, and sire breed × sex. All other sources of variation were tested using the residual mean square.

*$P < .05$.

**$P < .01$.

other lines. Line of dam differences were not significant among WWL, YWL, CTL, and MARC lines. In the IXL line, muscling score was emphasized as well as yearling weight. It is not evident why selection for muscling score would increase gestation length, but muscling scores and gestation length are generally greater for Continental European breeds, which are considered relatively more muscular than the British breeds (e.g., Limousin, Charolais, Simmental compared with Hereford-Angus [Smith et al., 1976]; or Gelbvieh, Maine Anjou, and Chianina compared with Hereford-Angus crosses [Gregory et al., 1978]). Among British or Continental breeds considered less muscular, gestation length has been significantly shorter in Holstein (Notter et al., 1978a) and Jersey crosses (Smith et al., 1976) than in Hereford-Angus crosses. However, in the present study, gestation length was longer in progeny of Longhorn sires than in those of Hereford-Angus crosses ($P < .05$). Consistent with many previous reports, male calves had significantly longer gestation length than females, and gestation length increased as age of dam increased (e.g., Smith et al., 1976; Gregory et al., 1978, 1979). Effects of sex of calf, age of dam, and year of birth were significant for gestation length. Gestation length was 1.8 d longer for males than for females ($P < .01$). Gestation length was shorter for cows calving at 3 (284.9 ± .7) and ≥12 yr of age (285.0 ± .5) than at 5 to 9 yr of age (286.4 ± .3) ($P < .05$). These effects are consistent with previous reports (Smith et al., 1976; Gregory et al., 1978, 1979, 1991).

Unassisted Calvings. Calving ease, as reflected by percentage of unassisted calvings, differed significantly among sire breeds, sires within sire breed, sexes, and ages of dam. Progeny of Shorthorn and Longhorn sires required less assistance than progeny of Piedmontese and Nellore sires or of AI-sired Hereford-Angus crosses ($P < .05$). Progeny of Shorthorn, Longhorn, Galloway, Gelbvieh, and Salers-sires required less calving assistance than progeny of Charolais sires ($P < .05$). Progeny of Galloway, Gelbvieh, Salers, Hereford-Angus AI or CU, Pinzgauer, Piedmontese, and Nellore sires did not differ significantly in unassisted calvings. Hereford dam lines did not differ significantly in unassisted calvings.

Perinatal Mortality and Survival from Birth to Weaning. Perinatal mortality (stillbirths and calves that died within 72 h) was relatively low (4.0%) and was only affected significantly by sire within breed, sex of calf, and line of dam within Herefords. Perinatal mortality was lower in females (3.2%) than in males (4.8%), which is consistent with results and trends of previous studies (Cundiff et al., 1974; Gregory et al., 1978, 1979). Perinatal mortality tended to be lower in the progeny out of dams from the line selected for yearling weight than from those out of unselected control line dams ($P < .05$, either by chi squared [Snedecor and Cochran, 1967] or by direct linear

Table 4. Least squares means and standard errors for birth and weaning traits for breed group of sire

Breed group	Gestation length, d	Unassisted calvings, %	Perinatal mortality, %	Survival, birth to weaning, %	Birth weight, kg	200-d weight, kg
Reference Hereford-Angus (HA)-×	283.7	94.4	2.4	95.9	35.2	210.1
1980s HA-×, AI	283.2	95.0	5.9	92.6	37.8	223.1
1980s HA-×, CU[a]	—	96.5	4.8	89.9	37.9	212.3
Charolais-× AI	285.9	88.6	4.2	91.0	40.6	231.3
Charolais-× CU[a]	—	92.9	6.9	88.7	40.0	224.2
Gelbvieh-× CU[a]	—	97.6	4.3	93.0	39.8	226.0
Pinzgauer-× CU[a]	—	95.9	1.7	95.0	40.0	224.4
Shorthorn-×	284.0	99.8	4.2	93.3	38.9	223.8
Galloway-×	285.8	97.9	2.4	94.2	36.2	209.5
Longhorn-×	286.8	99.9	4.1	92.7	31.4	199.0
Nellore-×	293.0	94.2	5.3	92.7	40.4	229.7
Piedmontese-×	287.3	94.6	4.6	92.4	37.8	220.0
Salers-×	285.1	97.3	4.3	92.9	38.1	225.5
LSD.05[b]	1.3	4.3	4.5	5.5	1.3	6.5
Genetic parameters[c]						
h^2	.378 ± .079	.097 ± .050	.090 ± .049	.041 ± .047	.349 ± .063	.182 ± .058
σ_p	4.66	18.1	19.2	24.2	4.6	23.5
σ_g	2.86	5.7	5.8	4.9	2.7	10.0
$2R/\sigma_g$	6.85	—	—	—	6.8	6.5

[a]Calves sired by natural service matings after a breeding period of 45 d by AI.
[b]Breed group differences larger than the least significant difference (LSD.05) are considered significant ($P < .05$).
[c]Genetic parameters: h^2 denotes heritability, σ_p denotes phenotypic standard deviation, σ_g denotes square root of estimated additive genetic variance, R denotes range or difference between the highest and lowest breed group means.

contrast assuming normal approximation for a binomial). However, no other line of dam contrasts was significant. Survival from birth to weaning averaged 93.0% and was not affected significantly by any source of variation included in the analysis of variance.

Birth Weight. Mean birth weight was 37.5 kg. Effects of sire breed, sire within sire breed, dam breed, sex, age of dam, year of birth, line within Hereford dams, breed of sire × breed of dam, breed of sire × sex of calf, breed of dam × year, and age of dam × year were significant for birth weight.

Birth weight of Longhorn-sired progeny were significantly lighter than Galloway-sired progeny, which were in turn significantly lighter than progeny of all other sire breeds. Hereford-Angus crosses by AI and natural service CU sires and progeny of Salers and Shorthorn sires did not differ significantly and had intermediate rankings for birth weight. Progeny by Charolais sires (AI and natural service CU matings), Nellore, Pinzgauer, and Gelbvieh sires ranked highest in birth weight and were significantly heavier than all other sire breeds except Shorthorn. Rankings for birth weight tended to be inversely related to those for unassisted calvings, except that progeny of Shorthorn and Salers sires required relatively low calving assistance considering their relatively heavy birth weights.

The breed of sire × sex of calf interaction resulted from a significantly greater effect of sex in Nellore crosses (males – females = 7.2 kg) than in any other breed cross. Differences between males and females for all other sire breeds did not differ significantly from the overall mean difference of 3.3 kg. This result is consistent with other reports of significant sire breed × sex interactions in *Bos indicus* × *Bos taurus* crosses vs *Bos taurus* × *Bos taurus* crosses (Cartwright et al., 1964; Gregory et al., 1979; Comerford et al., 1987; Paschal et al., 1991; Herring et al., 1996). This sire breed × sex interaction for birth weight of Nellore-sired male and female calves was not associated with a corresponding effect on gestation length. The difference in gestation length between male and female Nellore-sired calves (2.0 d) did not differ significantly from the main effect of sex on gestation length (1.8 d).

Progeny of Hereford dams were heavier at birth than progeny of Angus dams. The interaction of breed of sire × breed of dam breed resulted primarily from effects of heterosis in Hereford-Angus crosses. Within all other sire breeds, the effect of breed of dam differed from the main effect breed of dam (1.2 kg) only in Salers crosses, for which progeny of Hereford dams were 2.6 kg heavier than progeny of Angus dams ($P < .05$). The difference between progeny of Hereford and Angus dams tended to be smaller than average in Nellore crosses ($P < .1$; mean birth weight was 40.4 in progeny of both Hereford and Angus dams).

200-d Weight. Mean 200-d weight was 217.9 kg. Effects of sire breed, sire within sire breed, breed of dam, sex of calf, age of dam, year of birth, line within Hereford dams, breed of dam × year, sex × year, age of dam × year, and regression on date of birth all had significant effects on 200-d weight.

The 200-d weights of AI-sired Charolais crosses were significantly greater than those of Salers, CU Gelbvieh, CU Charolais, Shorthorn, CU Pinzgauer, 80's Hereford-Angus, and Piedmontese crosses, which were in turn significantly heavier than those of CU Hereford-Angus-, Galloway-, and reference-sired Hereford-Angus. Longhorn crosses had significantly lighter 200-d weights than all other crosses. Nellore crosses did not differ significantly from AI-sired Charolais or Salers crosses but were significantly heavier than all other breed groups. The high ranking of the Nellore relative to other breeds reflects in part the extra heterosis expected in *Bos indicus* × *Bos taurus* crosses relative to *Bos taurus* × *Bos taurus* crosses (Long, 1980).

Variation Within and Among Breeds. Effects of sire within breed were significant for all traits except calf survival from birth to weaning. Heritability estimates shown in Table 4 were of moderate magnitude for gestation length, and for weight at birth and 200 d. Heritability estimates were of low magnitude for percentage unassisted calvings, perinatal mortality, and survival from birth to weaning. These estimates are consistent with those of previous reports (e.g., Koch et al., 1982; Koots et al., 1994).

Significant effects of breed of sire and sire within breed indicate that genetic variation is important among and within breeds for gestation length, unassisted calvings, birth weight, and 200-d weight. It is useful to assess both sources of variation on the same scale ($\sigma_g = h\sigma_p$, where h^2 is heritability and σ_p^2 is phenotypic variance). The range (R) of difference between breeds is expected to represent half of the range between pure breeds. Thus, $2R/\sigma_g$ is expected to estimate the range among breeds relative to the pooled standard deviation for breeding value of individuals within breeds. The range of breed differences (2R) for gestation length, birth weight, and 200-d weight exceeds 6 σ_g, the range expected for breeding value of individuals within breeds for traits with a normal distribution. These results suggest that genetic variation between breeds is comparable in magnitude to additive genetic variation within breeds for these traits. This result is consistent with results pooled over the first three cycles of the GPE Program and summarized in this same way (Cundiff et al., 1986). For birth weight and 200-d weight, R represented contrasts among *Bos taurus* breeds, but for gestation length, the range of among breed group means was greatest for a *Bos indicus* vs *Bos taurus* contrast (R = 8.8 d between progeny sired by Nellore vs Angus-Hereford). The estimate for gestation length is expected to be inflated in part by greater heterosis effects in *Bos indicus* × *Bos taurus* crosses than in *Bos taurus* × *Bos taurus* crosses, but direct breed effects may also be increasing gestation length of Nellore-sired progeny relative to those by the other sire breeds in this experiment (Reynolds et al., 1980; Lemos et al., 1984; Paschal et al., 1991). Among *Bos taurus* breeds, the $2R/\sigma_g$ was approximately 2.9 for gestation length, or about half of the magnitude of genetic variation within breeds. It is not appropriate to apply this assessment to variation in binomial traits because their distributions are not expected to be symmetrical.

Implications

Significant differences exist among Hereford, Angus, Shorthorn, Longhorn, Nellore, Piedmontese, Salers, Charolais, Gelbvieh, and Pinzgauer topcross progeny in gestation length, unassisted calvings, birth weight, and 200-d weight. For gestation length, birth weight, and 200-d weight, the range for differences between breeds was estimated to be comparable in magnitude to the range for breeding value of individuals within breeds. Breed differences can generally be exploited to optimize performance levels in crosses or in composite populations relatively more quickly than performance can be optimized by intrapopulation selection.

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